GAMMA-RAY SPECTROSCOPY OF ^{191,193}Bi*

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Very neutron-deficient ^{191,193}Bi nuclei have been studied at the Department of Physics, University of Jyväskylä, Finland (JYFL) employing the Jurosphere II Ge-detector array coupled to the gas-filled recoil separator RITU and different tagging techniques. For the first time in heavy odd-mass nuclei, a collective band (oblate) is identified above the $2p$–$1h$ $(1/2^+)$ proton intruder state in ^{191}Bi. In both ^{191,193}Bi, a band based on isomeric $13/2^+$ state has been observed and oblate deformation for this state has been deduced.

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1. Introduction

Low lying proton intruder states are known in many odd-Z nuclei near the $Z = 82$ shell closure and associated with oblate-deformed shapes. Intruder $2p$–$1h$ $(1/2^+)$ states in odd-mass Bi isotopes are observed between the closed neutron shell nucleus ^{209}Bi and the mid-shell nucleus ^{187}Bi [1, 2] (Fig. 1). The excitation energy of these states decreases with decreasing neutron number and the reduction continues even at the mid-shell. This is unique compared to other odd-mass nuclei (see, for example, Tl in Fig. 1), where the excitation energies of intruder states have a parabolic behaviour as a function of neutron number with a minimum close to the mid-shell. One possible explanation for this behaviour in Bi isotopes is that near the mid-shell, instead, a prolate $1/2^+$ state is observed [3].

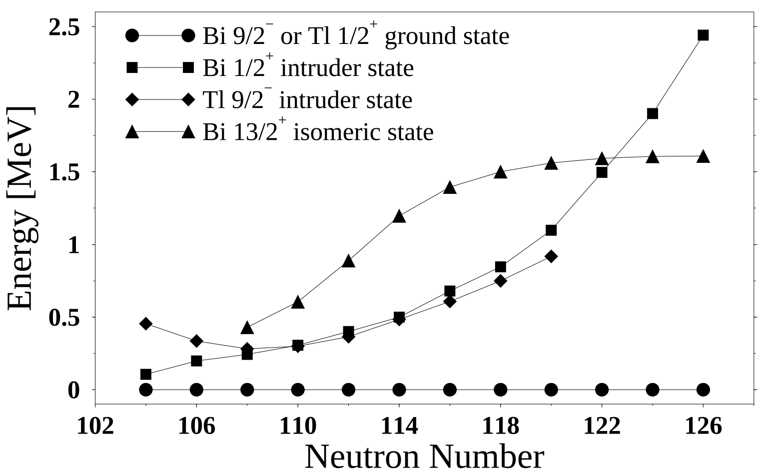

Fig. 1. Behaviour of the $13/2^+$ isomeric and the $1/2^+$ intruder state in Bi and the $9/2^-$ intruder state in Tl as a function of neutron number with respect to the ground state.

In Bi isotopes, an isomeric $13/2^+$ state feeding the $9/2^-$ ground state is seen and interpreted as a $\pi i_{13/2}$ state coupled to the even–even Pb core. The reason for the sudden reduction of excitation energy of this state with decreasing neutron number (see Fig. 1) could be either the increasing interaction of the $\pi i_{13/2}$ state with the $\nu i_{13/2}$ hole states which open up below $A = 197$, or a change in the underlying Pb core.

In this contribution, observation of states built on the $1/2^+$ state in ^{191}Bi, isomeric transitions de-exciting the $13/2^+$ states and band structures built on these states in ^{191,193}Bi, are reported.

2. Experimental methods

The heavy ion beams used in the present work were delivered by the K130 cyclotron and fusion evaporation residues were separated using the gas-filled separator RITU [4]. Prompt γ-rays were observed with 27 Compton suppressed HPGe detectors in the Jurosphere II array with absolute photopeak efficiency of $\sim$1.7% at 1.3 MeV. At the focal plane, recoils were implanted into a position sensitive silicon detector and γ-rays were detected with five Compton suppressed HPGe detectors close to the silicon detector. A Multiwire Proportional Avalanche Counter (MWPAC) was installed upstream from the silicon detector to separate recoil- and α-particle-like events with overlapping energies.

In the Recoil-Decay Tagging (RDT) method, recoils of interest are identified by observing their characteristic α-decay in the same silicon detector pixel within a time window depending on the α-decay half-life and implant rate. Prompt γ-rays observed in coincidence with the recoil and delayed γ-rays in coincidence with the α-decay are associated with the nucleus of interest. If a prompt or a delayed γ-ray is known, method of recoil gating or isomer tagging can be used.

3. Results

The nucleus ^{191}Bi was produced in the ^{142}Nd(^{52}Cr,$p2n$) reaction and $\sim$340000 α-decays of the $9/2^-$ ground state and $\sim$60000 α-decays of the $1/2^+$ intruder state were observed. An RDT analysis was performed to find states built on the $1/2^+$ state. A collective band was observed (Fig. 2(a)). *A* 429 keV γ-ray line in the focal plane spectrum was assigned to the isomeric $13/2^+$ to $9/2^-$ transition, for which a half-life of 533(7) ns was deduced. Recoil gating was used to build the tentative level scheme feeding the isomer (Fig. 2(b)).

The nucleus ^{193}Bi was produced by bombarding a ^{165}Ho target with a ^{32}S beam at energies from 144 to 159 MeV in 5 MeV steps. About 230000 α-decays of the $9/2^-$ state and $\sim$170000 α-decays of the $1/2^+$ state were observed. Due to the long α-decay half-life of the $9/2^-$ state (67 s), no correlation methods for this decay could be used. Knowing the energies of the $13/2^+$ to $9/2^-$ transitions in ^{195}Bi [5] and in ^{191}Bi and by comparing the excitation functions of candidate γ-ray lines in the expected energy range to that of the α-decay of the $9/2^-$ state, a 605 keV γ-ray line was assigned to this transition in ^{193}Bi. The tentative level scheme feeding the isomer is shown in Fig. 2(c).

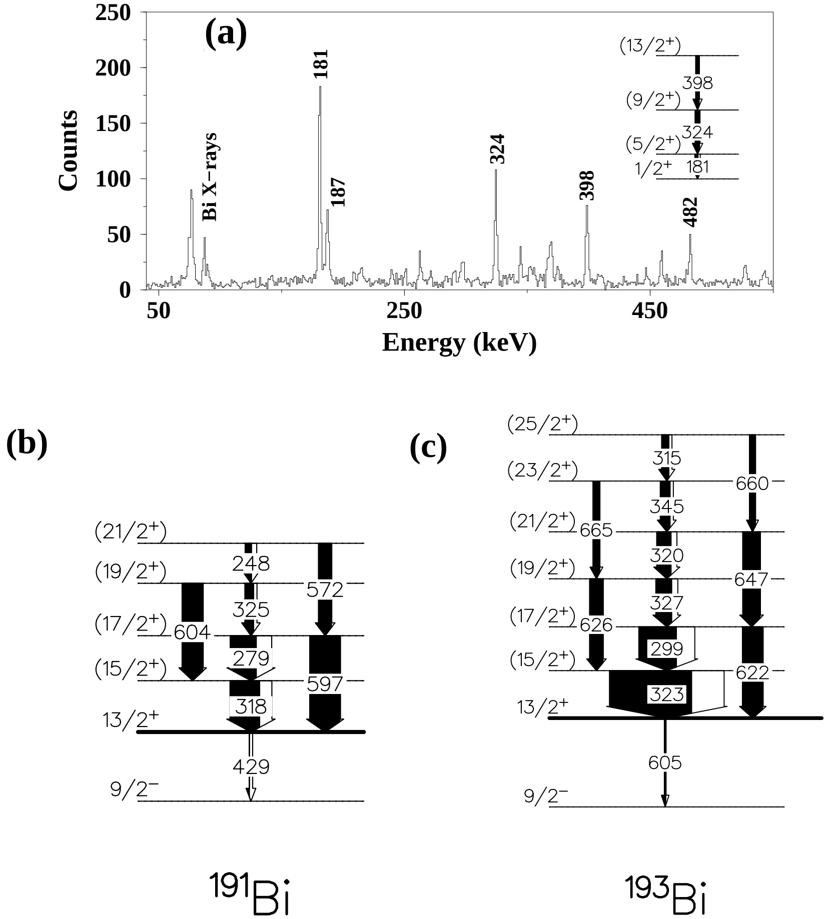

Fig. 2. (a) Prompt γ-rays tagged with the ^{191}Bi $1/2^+$ intruder state α-decay, the level scheme as an inset. (b) Band built on the $13/2^+$ state in ^{191}Bi and (c) in ^{193}Bi.

4. Discussion

The sequence of levels in the band based on the $1/2^+$ state in ^{191}Bi is quite similar to the extrapolated oblate band based on the 0^+ intruder state in ^{192}Po [6]. This implies that indeed, also the $1/2^+$ intruder state in ^{191}Bi is oblate deformed and that the predicted crossing of two different $1/2^+$ states [3] has not yet taken place in ^{191}Bi.

The energies of the observed $13/2^+$ isomeric states in ^{191,193}Bi continue the decreasing trend (Fig. 1). Strongly coupled bands identified above these $\pi i_{13/2}$ states indicate oblate deformation. The reason for the reduction of excitation energy could be better understood if information concerning this state in still more neutron-deficient Bi isotopes could be obtained.

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